THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**BIOLOGICAL WASTEWATER TREATMENT – NITRIFICATION AND DENITRIFICATION FOR NITROGEN REDUCTION**	
APPLICATION:	**REDUCTION OF NITROGEN IN DOMESTIC WASTEWATER FROM INDIVIDUAL RESIDENTIAL HOMES**	
TECHNOLOGY NAME:	**BIOCLERE™ MODEL 16/12**	
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of a fixed film trickling filter biological treatment system for nitrogen removal for residential homes. This verification statement provides a summary of the test results for the Aquapoint, Inc. Bioclere™ Model 16/12 system. The Barnstable County (Massachusetts) Department of Health and the Environment (BCDHE) performed the verification testing.

The EPA created the Environmental Technology Verification (ETV) Program to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups consisting of buyers, vendor organizations, and permitters, and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are

conducted in accordance with rigorous quality assurance protocols to ensure that data of known and verifiable quality are generated and that the results are defensible.

ABSTRACT

Verification testing of the Aquapoint, Inc. (AQP) Bioclere™ Model 16/12 was conducted over a thirteen month period at the Massachusetts Alternative Septic System Test Center (MASSTC), located at Otis Air National Guard Base in Bourne, Massachusetts. Sanitary sewerage from the base residential housing was used for the testing. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the Bioclere™ system. The verification test included monthly sampling of the influent and effluent wastewater, and five test sequences designed to test the unit response to differing load conditions and power failure. The Bioclere™ system proved capable of removing ammonia nitrogen in the aerobic unit and nitrate in the anaerobic/anoxic primary tank. The influent total nitrogen (TN), as measured by the TKN, averaged 37 mg/L with a median of 38 mg/L. The effluent TN average 16 mg/L over the verification period, with a median concentration of 14 mg/L, which included an average TKN concentration of 10 mg/L and a median concentration of 6.3 mg/L. The system operating conditions (pump and timer settings) remained constant during the test. Only routine maintenance and system checks were performed for most of the test, except when a nozzle-plugging problem occurred. The plugged nozzles impacted treatment performance, but performance improved quickly once they were cleared.

TECHNOLOGY DESCRIPTION

The AQP, Inc. Bioclere™ Model 16/12 uses a fixed film trickling filter for wastewater treatment. A complete treatment system has two stages of treatment. The first stage of treatment occurs in the primary tank (a 1,000 gallon single compartment septic tank) in which the solids are settled and partially digested. Septic tank effluent flows by gravity to the Bioclere™ unit, which is a separate system that provides secondary wastewater treatment. Microorganisms present in the wastewater attach to the Bioclere™ proprietary plastic filter media, and use the nutrients and organic materials provided by the constant supply of fresh wastewater to form new cell mass. The open spaces within the media allow air to freely pass through, providing oxygen to support the microorganisms.

The system has a recycle line for pumping of recycled solids from the Bioclere™ clarifier section (located below the plastic media) back to the primary tank. The pump operated for 1.5 minutes every 2.5 hours during the test, controlling the recycle rate to the primary tank. A dosing pump, set to run on a 3 minutes on/5 minute off cycle, circulated treated effluent from the clarifier section back the top of the unit, where the wastewater is sprayed over the media using a manifold and nozzle system. Air (oxygen) is supplied to the Bioclere™ by a fan located on the top of the unit, which runs continuously.

The Bioclere™ system is designed to remove total nitrogen from the wastewater by nitrification and denitrification. Nitrification occurs in the aerobic Bioclere™ unit, where ammonia nitrogen is converted to nitrite and nitrate (predominately nitrate). Denitrification occurs in the anaerobic/anoxic primary tanks, where the nitrite/nitrate is converted to nitrogen. The verification testing was performed using a full scale, commercially available unit, which was received as a self-contained system ready for installation.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site, initially funded by the State of Massachusetts and operated by BCDHE, is located at the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base residential housing and sanitary wastewater from other military buildings for use in testing. A

chamber located in the main sewer line upstream of the base wastewater treatment facility provides a location to obtain untreated wastewater. The raw wastewater, after passing through a one-inch bar screen, is pumped to a dosing channel at the test site. This channel is equipped with four recirculation pumps, which are spaced along the channel length to ensure mixing such that the wastewater is of similar quality at all locations along the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

All methods and procedures followed the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, dated November 2000. The Bioclere™ was installed by a contractor, in conjunction with the BCDHE support team in June 1999 as part of an earlier test program. The unit was installed in accordance with the Operations and Maintenance Manual supplied by AQP. In order to prepare for ETV testing, the entire Bioclere™ system was emptied of wastewater and cleaned. Solids were removed from the primary tank and the clarifier section of the Bioclere™ filter unit. All pumps, lines, and associated equipment were cleaned. The filter media was repeatedly flushed and solids removed from the bottom of the unit. Clean water was recirculated to further clean the media and lines. The entire unit was then drained and remained off until the startup period.

In early January 2001, fresh water was added to the unit and the system was cycled for several days to make sure the unit was operating properly, the dosing pumps were calibrated, and the PLC was working properly. An eight-week startup period, following the startup procedures in the AQP Technical Manual, allowed the biological community to become established and allowed the operating conditions to be monitored. Startup of the cleaned Bioclere™ system began on January 15, 2001, when the primary tank was filled approximately two thirds (2/3) full with clean water and one third (1/3) with raw wastewater from the dosing channel. The dosing sequence was then started, with the unit's pumps and timers on the factory default settings.

The system was monitored during the startup period through visual observation, routine calibration of the dosing system, and collection of influent and effluent samples. Six sets of samples were collected for analysis. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS. The effluent was analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, dissolved oxygen, NO_2, and NO_3.

The verification test consisted of a thirteen-month test period, incorporating five sequences with varying stress conditions simulating real household conditions. The five stress sequences were performed at two-month intervals, and included washday, working parent, low loading, power failure and vacation test sequences. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_3, NO_2, NO_3). Biochemical (BOD_5) and carbonaceous biochemical oxygen demand ($CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall system treatment performance. Operational characteristics, such as electric use, residuals generation, labor to perform maintenance, maintenance tasks, durability of the hardware, and noise and odor production, were also monitored.

The Bioclere™ system has a design capacity of 400 gallons per day. The verification test was designed to load the system at design capacity (± 10 percent) for the entire thirteen-month test, except during the low load and vacation stress tests. The Bioclere™ system was dosed 15 times per day with approximately 26-27 gallons of wastewater per dose. The unit received five doses in the morning, four doses mid-day, and six doses in the evening. The dosing volume was controlled by adjusting the pump run time for each cycle, based on twice weekly pump calibrations.

The sampling schedule included collection of twenty-four hour flow weighted composite samples of the influent and effluent wastewater once per month under normal operating conditions. Stress test periods were sampled on a more intense basis with six to eight composite samples being collected during and following each stress test period. Five consecutive days of sampling occurred in the twelfth month of the verification test. All composite samples were collected using automatic samplers located at the dosing channel (influent sample) and at the discharge of the Bioclere™ unit. Grab samples were collected on each sampling day to monitor the system pH, dissolved oxygen, and temperature.

All samples were cooled during sample collection, preserved, if appropriate, and transported to the laboratory. All analyses were in accordance with EPA approved methods or Standard Methods. An established QA/QC program was used to monitor field sampling and laboratory analytical procedures. QA/QC requirements included field duplicates, laboratory duplicates and spiked samples, and appropriate equipment/instrumentation calibration procedures. Details on all analytical methods and QA/QC procedures are provided in the full Verification Report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the AQP Bioclere™ Model 16/12 at MASSTC began on January 15, 2001, when the Bioclere™ pumps and timers were activated, and the initial dosing cycles activated. Flow was set at 400 gpd, resulting in 15 doses per day with a target of 26.7 gallons per dose. The startup period continued until March 13, 2001. Six samples of the influent and effluent were collected during the startup period. Verification testing began on March 13, 2001 and continued for 13 months until April 17, 2002. The extra month of dosing and sampling (13 months versus the planned 12 months) was added to the test to obtain data on the system response as the temperatures began to rise in the spring. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

Overall, the unit started up with no difficulty. The startup instructions in the Technical Manual were easy to follow and provided the necessary instructions to get the unit up and operating. No changes were made to the unit during the startup period, and no special maintenance was required. Daily observation showed that biological growth was established on the media.

The Bioclere™ system performance for $CBOD_5$, TSS, and TN remained relatively steady throughout the startup period. Effluent $CBOD_5$ varied between 13 and 51 mg/L, with the lowest value at the end of the startup period. There was some indication of TN reduction occurring, with effluent concentrations varying between 27 and 36 mg/L compared to influent concentrations of 34 to 46 mg/L. However, it did not appear that the nitrifying organisms had established themselves in the system. Low wastewater and ambient temperatures were considered the primary reason for the slow trend toward improved reduction in both $CBOD_5$ and TN. The temperature of the effluent wastewater was about 5 ^{o}C when the unit was started and remained in the 5 to 7 ^{o}C range through March 13.

Verification Test Results

The daily dosing schedule during normal operations remained constant through the entire verification test. A daily dosing sequence of 15 doses was performed every day except during the low load (September 2001) and vacation stress (February 2002) periods. Volume per dose and total daily volume varied only slightly during the test period. The daily volume averaged on a monthly basis ranged from 387 to 407 gallons per day. This compared closely to the 400 gallons per day design capacity.

The sampling program emphasizes sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods, with the remaining samples spread over

the remaining months (monthly sampling). Therefore, impacts of a stress test or an upset condition occurring during concentrated sampling periods can have an impact on the calculation of average values. Both average and median results are presented, as the median values compared to average values can help in analyzing these impacts. In the case of the Bioclere™ results, the median concentrations are lower than the average concentrations due to the upset condition when the nozzles plugged during the working parent stress test.

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had an average BOD_5 of 210 mg/L and a median BOD_5 of 200 mg/L. The TSS in the influent averaged 160 mg/L and had a median concentration of 140 mg/L. The Bioclere™ effluent showed an average $CBOD_5$ of 14 mg/L with a median $CBOD_5$ of 10 mg/L. The average TSS in the effluent was 16 mg/L and the median TSS was 10 mg/L. $CBOD_5$ concentrations in the effluent typically ranged from 4 to 20 mg/L, and TSS ranged from 4 to 17 mg/L, except during an apparent upset condition that occurred in July 2001.

Table 1. BOD_5/$CBOD_5$ and TSS Data Summary

	BOD_5	$CBOD_5$		TSS		
	Influent (mg/L)	**Effluent (mg/L)**	**Percent Removal**	**Influent (mg/L)**	**Effluent (mg/L)**	**Percent Removal**
Average	210	14	93	160	16	90
Median	200	10	95	140	10	93
Maximum	380	60	98	410	62	98
Minimum	72	3.5	78	40	2	63
Std. Dev.	70	11	5.0	71	16	7.0

Note: The data in Table 1 are based on 53 samples.

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had an average TKN concentration of 37 mg/L, with a median value of 38 mg/L, and an average ammonia nitrogen concentration of 23 mg/L, with a median of 23 mg/L. Average TN concentration in the influent was 37 mg/L (median of 38 mg/L) based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The Bioclere™ effluent had an average TKN concentration of 10 mg/L and a median concentration of 6.3 mg/L. The average NH_3-N concentration in the effluent was 6.2 mg/L and the median value was 2.8 mg/L. The nitrite concentration in the effluent was low, averaging 0.45 mg/L. Effluent nitrate concentrations averaged 5.3 mg/L with a median of 4.4 mg/L. Total nitrogen was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), nitrite and nitrate. Average TN in the Bioclere™ effluent was 16 mg/L (median 14 mg/L) for the thirteen month verification period. The Bioclere™ system averaged a 57 percent reduction of TN for the entire test, with a median removal of 64 percent.

Verification Test Discussion

Beginning in late March and early April, temperatures began to increase and the nitrifying population clearly became established, as indicated by the decrease in the TKN and NH_3 concentrations in the effluent. Nitrate concentrations increased somewhat in this same period, but the data show that denitrification was also occurring. The concentration of organic matter in the effluent, as measured by $CBOD_5$ and TSS concentrations, also decreased. During May and June, the TN concentration in the effluent was in the range of 8.8 to 11 mg/L. The Washday stress test in May 2001 showed no negative impact on nitrogen reduction.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Effluent
Average	37	10	23	6.2	37	16	5.2	0.45	15
Median	38	6.3	23	2.8	38	14	4.4	0.34	15
Maximum	46	35	27	22	46	36	14	1.5	23
Minimum	24	1.9	18	0.7	24	6.2	<0.1	0.07	7.4
Std. Dev.	4.4	10	2.1	7.0	4.4	8.4	3.5	0.26	4.9

Note: The data in Table 2 are based on 53 samples, except for Temperature, which is based on 51 samples.

In early July 2001, the data show that there was loss of the nitrifying population in the unit, with total nitrogen levels in the effluent of 25 to 36 mg/L. The effluent concentrations of $CBOD_5$ and TSS also increased during this time, indicating the system was under stress. It was discovered that two of the nozzles in the Bioclere™ unit were clogged. AQP responded to the problem and cleaned the nozzles, and within two to three weeks, the TN concentration decreased to 9.4 mg/L, similar to the period before the problem occurred. The $CBOD_5$ and TSS levels in the effluent also decreased, returning to the levels measured before the nozzle plugging occurred. The loss of nitrogen and $CBOD_5$ removal efficiency during the nozzle-plugging problem makes it unclear whether the Working Parent dose sequence would have had an impact on the system.

Once the nitrifying population was reestablished, the Bioclere™ system continued to reduce the total nitrogen concentration on a consistent basis (7.7 to 11 mg/L) until December. This period included the Low Dose sequence, when the Bioclere™ was dosed with 50 percent of the daily design loading, which appears to have had no impact on the system operation. The temperature of the wastewater began to decrease in October, as would be expected. While the trend was not clear, the late November sample indicated a lower removal of nitrogen was occurring as compared to September and October. The Power Failure stress test (power shut off for 48 hours) was started on December 3, 2001. Sample results for the post stress period showed effluent total nitrogen had increased to 18 mg/L, while subsequent monitoring over the next few weeks showed the total nitrogen concentration to be in the range of 6.2 to 19 mg/L. Most of the concentrations were in the 13 to 19 mg/L range, with influent levels of 35 to 46 mg/L. The lower nitrogen removal efficiencies in the December to February period correspond to lower temperatures in the wastewater. It appears that the Power Failure stress test may have contributed to the change in efficiency by stressing the nitrifying population. The lower temperatures in the wastewater appeared to have slowed the total nitrogen removal and possibly the re-establishment of the nitrifying population.

The Vacation stress test in February had no noticeable impact on the system performance for nitrogen removal. The last scheduled samples for total nitrogen in the first week of March showed that the Bioclere™ system was removing TN in the 60 to 66 percent range, somewhat lower than the efficiencies of the previous summer and fall. The temperature of the wastewater appeared to have an effect on the nitrogen reduction levels based on both the startup data and on the December 2001 to February 2002. The test period was extended one additional month to determine if removal would improve as the wastewater temperature increased. The final sample showed a sharp decrease in TN from 16 mg/L on March 8 to 8 mg/L on April 17. During this period, the temperature of the wastewater increased to 14.3 ^{o}C from 9.2 ^{o}C.

Operation and Maintenance Results

Noise levels associated with mechanical equipment were measured once during the verification period using a decibel meter. Measurements were made one meter from the unit, and one and a half meters above

the ground, at 90° intervals in four (4) directions. The average decibel level was 49.5, with a minimum of 45.5 and maximum of 52.8. The background level was 37.7 decibels.

Odor observations were made monthly for the last eight months of the verification test. The observations were qualitative based on odor strength (intensity) and type (attribute). Observations were made during periods of low wind velocity (<10 knots), at a distance of three feet from the treatment unit, and recorded at 90° intervals in four directions. There were no discernible odors found during any of the observation periods.

Electrical use was monitored by a dedicated electric meter serving the Bioclere™ system. The average electricity use was 4.2 kW/day. The Bioclere™ system does not require or use any chemical addition as part of the normal operation of the unit.

During the test, very few problems were encountered with the operation of the system with the exception of the plugged nozzles after five and half months of operation. The plugging problem was discovered when the effluent's visual characteristic changed and had notably more suspended solids. In addition, during the nozzle plugging, the noise level of the spray hitting the inside of the media containment structure was slightly louder, signaling higher flow through one of the nozzles and overloading of a portion of the media bed. The nozzles were cleaned again in the fall by AQP in accordance with the quarterly maintenance check recommended in their O&M manual. AQP installed a new set of helical nozzles in January 2002. These nozzles required no additional cleaning through the remainder of the test. AQP believes that the nozzle plugging problem was a unique occurrence as this type of unit had been operated at MASSTC and many other locations without a problem. AQP added a statement regarding the nozzle issue at the end of the Verification Report.

Routine quarterly maintenance by a person knowledgeable of the treatment system was recommended in the O&M manual, and was confirmed to be appropriate by the BCDHE staff during the test. The maintenance should involve checking the two pumps (recirculating and recycling), the fan, and cleaning the distribution manifold and nozzles. The maintenance check should also include measurement of the sludge depth in the primary tank, observation of the condition of the media, and a visual inspection of the effluent. Pump cycle times should be verified and alarms checked.

The treatment unit itself proved durable for the duration of the test and appears to generally be a durable fiberglass design. The piping is standard PVC that is appropriate for the applications. Pump and level switch life are always difficult to estimate, but the components used are made for wastewater applications by a reputable and known manufacturer.

Quality Assurance/Quality Control

QA audits of the MASSTC and BCDHE laboratory were completed by NSF International during testing. NSF personnel completed a technical systems audit to assure the testing was in compliance with the test plan, a performance evaluation audit to assure that the measurement systems employed by MASSTC and the BCDHE laboratory were adequate to produce reliable data, and a data quality audit of at least 10 percent of the test data to assure that the reported data represented the data generated during the testing. In addition to quality assurance audits performed by NSF International, EPA QA personnel conducted a quality systems audit of NSF International's QA Management Program, and accompanied NSF during audits of the MASSTC and BCDHE facilities.

Original signed by	*Original signed by*
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Availability of Supporting Documents

Copies of the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, dated November 2000, the Verification Statement, and the Verification Report are available from the following sources:

1. ETV Water Quality Protection Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

EPA's Office of Wastewater Management has published a number of documents to assist purchasers, community planners and regulators in the proper selection, operation and management of onsite wastewater treatment systems. Two relevant documents and their sources are:

1. *Handbook for Management of Onsite and Clustered Decentralized Wastewater Treatment Systems* http://www.epa.gov/owm/onsite
2. *Onsite Wastewater Treatment Systems Manual* http://www.epa/gov/owm/mtb/decent/toolbox.htm